Cadmium in American Lobster *(Homarus americanus)* from the Area of Belledune Harbour, New Brunswick, Canada - A Summary of Five Years' Study

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CADMIUM IN AMERICAN LOBSTER (*HOMARUS AMERICANUS*) FROM THE AREA OF BELLEDUNE HARBOUR, NEW BRUNSWICK, CANADA- A SUMMARY OF FIVE YEARS STUDY

by

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ABSTRACT

Uthe, J.F. and C.L. Chou. 1985. Cadmium in American lobster (Homarus americanus) from the area of Belledune Harbour, New Brunswick, Canada - A summary of five years study. Can. Tech. Rep. Fish. Aquat. Sci. 1342: vi + 20 p.

A study of cadmium concentrations in digestive gland and cooked meat from individual lobsters captured in the area of Belledune Harbour, New Brunswick has been carried out annually since 1980. Mean cadmium concentrations in digestive glands from lobsters captured deep within the harbour peaked at 223 mg/kg wet wt. in 1981 and levelled off at 73.1 and 75.4 mg/kg in 1983 and 1984, respectively. This reduction probably resulted from the opening of an aqueous effluent and plant run-off treatment facility in late 1980. Control lobster digestive glands contained 3.30-4.83 mg cadmium/kg during the same period. Cadmium concentrations in cooked meat from harbour lobsters were too high to allow any use to be made of harbour lobster since 1979. Lead concentrations in cooked meat from harbour lobsters, although elevated compared to controls were within the same range reported for commercial lobster meat preparations. Concentrations of arsenic, copper and silver were not significantly different from control values. A mechanism for allowing the commerical fishery to re-open in the harbour under strict control is suggested.

RÉSUMÉ

Uthe, J.F. and C.L. Chou. 1985. Cadmium in American lobster (Homarus americanus) from the area of Belledune Harbour, New Brunswick, Canada - A summary of five years study. Can. Tech. Rep. Fish. Aquat. Sci. 1342: vi + 20 p.

Chaque année depuis 1980, on détermine la concentration du cadmium dans la glande digestive et dans la viande cuite de homards capturés dans la région de Belledune Harbour, Nouveau-Brunswick. La concentration moyenne de cadmium dans la glande digestive de homards capturés profondément à l'intérieur du port a atteint un sommet de 223 mg/kg de poids frais en 1981 pour se stabiliser à 73,1 et 75,4 mg/kg en 1983 et 1984 respectivement. Cette baisse résulte probablement de la mise en service d'installations de traitment des effluents aqueux et des effluents d'usine à la fin de 1980. Durant la même période, la glande digestive de homards témoins contenait entre 3,30 et 4,83 mg de cadmium/kg. Depuis 1979, la concentration de cadmium dans la viande cuite des homards du port était trop élevée pour permettre l'exploitation de ce homard. La concentration de plomb dans la viande cuite de homards du port était élevée comparativement à celle des témoins, mais elle était dans la même gamme de valeurs que celle signalée dans le cas des préparations commerciales de viande de homard. Les concentrations d'arsenic, de cuivre et d'argent n'étaient pas significativement différentes des valeurs observées chez les témoins. On propose un mécanisme faisant appel à une surveillance très stricte permettant la reprise de la pêche commerciale dans le port.

INTRODUCTION

Concern about trace metal levels in American lobsters (Homarus americanus) captured in the area of Belledune Harbour, New Brunswick was raised in 1980 when the Department of Fisheries and Oceans received a report (Levaque Charron 1981) which showed that cadmium (Cd) levels in claw and tail muscle of lobsters captured within Belledune Harbour had risen substantially between 1974 and 1979. Cd levels in digestive gland (hepatopancreas, tomalley, mid-gut gland), first measured in 1979, frequently exceeded 100 mg/kg wet wt. Since both muscle and digestive gland are eaten in Canada, these high Cd levels, confirmed by the Department early in 1980, resulted in the harbour being closed to commercial lobster fishing in 1980 and the imposition of a controlled fishery zone surrounding the harbour (Uthe et al. 1982). Lobsters captured within this zone by commercial fishermen have received special handling and inspection to ensure that consumers were not exposed to excessive amounts of Cd (Uthe et al. 1982). The major source of Cd to the harbour was from lead concentrate and secondary materials processed by a lead smelter located on the shore of the harbour. Until the fall of 1980 effluents discharged into the harbour had relatively high levels of Cd. Effective treatment of aqueous effluents from the plant began in 1980 and have reduced the Cd discharge to the harbour by more than 95% (Uthe et al. 1983). Additional contamination was caused by runnoff from the plant property. This runoff was diverted to the treatment plant in 1980 (Bewers et al. 1985).

A survey of Cd levels in lobsters from the area has been conducted prior to the opening of the commercial lobster season annually since 1980. Cd concentrations were determined in digestive glands and cooked meat (meat from tail and both claws pooled) from lobsters captured at a number of designated sites (Fig. 1) in and around Belledune Harbour. This report summarizes results from the five-year study (1980-1984) of tissue Cd and other trace metals as they were studied at various times during the project.

MATERIALS AND METHODS

Details of lobster capture, tissue sampling and analytical procedures used for Cd are described in Uthe et al. (1983). Arsenic (As) levels were determined by the method of Freeman et al. (1976). Flame atomic absorption spectrophotometry was used to determine copper (Cu) and silver (Ag) in nitric acid tissue digests. These methods have been used successfully in intercomparative studies sponsored by the International Council for the Exploration of the Sea (Holden and Topping 1981). Lead (Pb) was determined by graphite furnace atomic absorption spectrophotometry of nitric acid digests. This method has also been confirmed by intercomparison studies (Berman 1984).

RESULTS AND DISCUSSION

CADMIUM IN LOBSTER DIGESTIVE GLAND

The statistical distributions of Cd levels in digestive glands from lobsters captured in and around Belledune Harbour were abnormal (Uthe et al.

Figure 1 - Sample site locations used for the annual geographical survey of cadmium levels in lobster hepatopancreas.

1980). Normal distributions were found with logarithmically transformed data ($\log_{10}$ mg Cd/kg tissue wet wt.). Thus, geometric mean levels are shown in Table 1. The highest mean Cd concentrations were found in lobsters captured deep were within the harbour at the Harbour West (HW) sampling site (73.1 mg/kg in 1980, 223 mg/kg in 1981), lower but still very elevated levels at the Harbour East (HE) sampling site (32-77 mg/kg) and levels decreasing as the sample locations moved further away from the harbour mouth to mean levels of 3.30-4.83 mg/kg at the control (Heron Island) site. Cd levels decreased more slowly in a south-easterly direction from the harbour mouth than in the northwesterly direction, most likely due to the prevailing current in the area.

Over five years a generalized picture of contamination emerges. Between 1980 and 1981 mean Cd levels generally increased. Between 1981 and 1983 levels within the harbour and controlled fishing zone generally decreased with little, if any, change between 1983 and 1984 (Fig. 2). The statistical interpretation of these results is not simple. Although there is a significant relationship between Cd levels in the digestive gland and the total weight of the lobster (Uthe et al. 1980) analysis of covariance (ANCOVA) of the data did not give satisfactory corrections for effects of annual animal weight differences to allow one to estimate temporal changes in Cd levels without this complicating factor. Improved statistical analysis is being carried out.

CADMIUM IN COOKED LOBSTER MEAT

Cd levels in cooked meat were much lower than in the corresponding digestive gland levels (Table 2). The technical difficulties associated with removal of the meat from the cooked parts of the lobster and the necessity of employing furnace atomic absorption spectrophotometry to measure the lower Cd levels in the cooked meat resulted in only a sub-sample of the total number of animals being analyzed for cooked meat Cd levels. Cooked meat was not analyzed in 1980. The geographical distribution of Cd mean levels in cooked meat paralleled that observed for the digestive gland. Highest cooked meat Cd levels were present in harbour animals with lower levels found in those animals captured immediately outside of the harbour within the controlled fishery zone and yet lower levels in cooked meat from animals captured outside of the controlled fishing zone. Cd levels in cooked meat decreased between 1981 and 1983 with little change occurring between 1983 and 1984 (Fig. 3). Again the inability of analysis of covariance to satisfactorily correct for the annual animal weight differences requires better statistical modelling of the system.

Some small amount of Cd still enters the marine environment from operations carried out at the lead plant. Prior to 1980, it was estimated that the plant emitted about 4 tonnes Cd/yr to the atmosphere and about 25 tonnes in aqueous effluents. Since 1981 (Levaque Charron personal communication) the operation of the aqueous treatment plant has reduced the aqueous Cd emissions by more than 95% resulting in less than 1 tonne/yr entering the marine environment. The amount of atmospheric Cd which enters the marine environment is unknown. The lack of substantial change in Cd levels between 1983 and 1984 suggests that the major effect of the effluent and runoff clean-up program implemented at the smelter in 1980 has occurred, and that changes in future levels will occur at a slower rate.

Table 1. Geometric mean cadmium levels (mg/kg wet wt.) in digestive gland of lobsters captured in the area of Belledune Harbour, New Brunswick (ranges are shown in parentheses).

Sample Site	Year	$\overline{X}g$	N	Mean total animal wt. (g) (±s.d.)
Within Belledune Harbour				
Harbour West	1984	75.4 (11.75-262)	30	534±243 (181-1180)
	1983	73.1 (11.3-348)	40	383±242 (108-1073)
	1982	147 (8.79-728)	35	503±269 (158-1515)
	1981	223 (40-652)	43	464±207 (169-1080)
	1980	174 (47.6-372)	28	532±230 (151-965)
Harbour East	1984	77.0 (8.24-537)	15	632±293 (176-1196
	1983	32.5 (8.21-254)	25	436±146 (153-793)
	1982	76.3 (14.7-470)	35	542±213 (286-1056)
	1981	70.1 (11.7-390)	43	479±193 (177-1042)
	1980	62.3 (13.7-263)	28	390±275 (156-1057)

Table 1 Con't. (a)

Sample Site	Year	$\bar{X}g$	N	Mean total animal wt. (g) (±s.d.)
Within Controlled Fishery Zone				
L1W	1984	19.9 (6.23-170)	15	446±196 (284-918)
	1983	16.2 (5.98-193)	25	335±123 (136-636)
	1982	14.3 (2.82-308)	33	417±210 (134-1118)
	1981	20.0 (8.78-113)	28	451±227 (107-1119)
	1980	11.8 (3.34-119)	29	392±200 (222-1000)
LOBE	1984	-	-	-
	1983	32.6 (923-155.3)	13	519±227 (184-1046)
	1982	46.7 (6.68-287)	27	495±213 (173-877)
	1981	58.1 (8.66-393)	27	462±209 (199-822)
	1980	24.1 (4.65-209)	29	416±229 (156-822)

Table 1 Con't. (b)

Sample Site	Year	$\bar{X}g$	N	Mean total animal wt. (g) (±s.d.)
L1E	1984	33.1 (1.81-204)	15	491±195 (252-877)
	1983	31.6 (8.39-203)	24	365±159 (155-686)
	1982	40.4 (5.42-132)	36	330±153 (164-735)
	1981	44.0 (4.63-166)	33	289±68 (180-502)
	1980	28.1 (4.13-119)	31	293±124 (222-891)
L4E	1984	17.3 (8.14-82.1)	15	480±190 (208-796)
	1983	23.8 (6.53-177)	28	405±276 (138-1124)
	1982	23.8 (4.96-122)	38	342±157 (146-1037)
	1981	43.3 (7.69-151)	46	323±133 (178-737)
	1980	28.0 (7.13-53.9)	26	319±156 (168-762)

Table 1 Con't. (c)

Sample Site	Year	$\overline{X}g$	N	Mean total animal wt. (g) (±s.d.)
Outside Controlled Fishery Zone				
L6E	1984	9.50 (4.50-60.5)	15	394±153 (239-792)
	1983	18.4 (6.38-87.3)	25	386±157 (174-764)
	1982	15.6 (5.27-54.3)	35	315±131 (166-711)
	1981	25.9 (10.3-60.9)	30	307±131 (145-581)
	1980	17.3 (6.10-50.9)	19	278±98 (154-532)
Petit Rocher	1984	7.90 (4.10-25.8)	15	310±103 (213-551)
	1983	7.49 (204-20.5)	25	275±68.5 (167-398)
	1982	12.8 (5.20-56.6)	36	315±111 (130-566)
	1981	19.7 (5.63-39.7)	41	404±153 (218-787)
	1980	11.6 (6.26-22.1)	31	272±41 (199-381)

Table 1 Con't. (d)

Sample Site	Year	$\bar{X}g$	N	Mean total animal wt. (g) (±s.d.)
Heron Island	1984	3.30 (1.60-13.80)	15	387±181 (217-811)
	1983	4.09 (1.88-9.41)	26	454±188 (206-977)
	1982	4.69 (2.08-10.05)	23	355±126 (137-619)
	1981	4.83 (2.89-12.0)	27	387±102 (262-752)
	1980	3.85 (2.19-8.26)	30	349±53 (235-506)

Table 2. Geometric mean cadmium levels (mg/kg wet wt.) in cooked lobster tail and claw meat and uncooked digestive gland.

Sample Site	Year	Mean total animal wt.±s.d.	COOKED MEAT $\bar{X}g$	COOKED MEAT Range	DIGESTIVE GLAND N	DIGESTIVE GLAND $\bar{X}g$	DIGESTIVE GLAND Range
Within Belledune Harbour							
Harbour West	1984	534±243	0.427	(0.054-2.69)	30	75.4	(11.75-262)
	1983	465±252	0.48	(0.11-1.59)	25	74.2	(11.3-348)
	1982	511±317	0.74	(0.11-3.26)	21	165	(33.3-728)
	1981	433±144	0.89	(0.42-3.06)	9	150	(58.0-572)
Harbour East	1984	632±293	0.203	(0.069-1.08)	15	77.0	(8.24-537)
	1983	467±177	0.240	(0.07-1.53)	11	44.5	(12.0-254)
	1982	551±209	0.23	(0.04-0.76)	12	62.5	(14.7-470)
	1981	556±218	0.35	(0.07-1.28)	11	67.9	(17.0-355)
Within Controlled Fishery Zone							
L1W	1984	446±196	0.079	(0.010-0.450)	15	19.9	(4.52-170)
	1983	373±136	0.052	(0.022-1.06)	12	17.43	(5.98-193)
	1982	528±209	0.03	(0.03-0.06)	6	8.77	(5.76-17.5)
	1981	606±267	0.12	(0.03-1.82)	10	29.6	(8.30-135)

Table 2 Con't.

Sample Site	Year	Mean total animal wt±s.d.	COOKED MEAT $\bar{X}g$	COOKED MEAT Range	DIGESTIVE GLAND N	DIGESTIVE GLAND $\bar{X}g$	DIGESTIVE GLAND Range
L1E	1984	491±195	0.167	(0.010-1.80)	15	33.1	(1.81-204)
	1983	297±117	0.11	(0.02-0.66)	11	29.4	(8.39-70.7)
	1982	330±145	0.18	(0.05-0.43)	10	47.8	(10.3-134)
	1981	314±81	0.21	(0.047-0.682)	10	34.3	(8.15-130)
L4E	1984	480±190	0.07	(0.019-0.214)	15	17.3	(8.14-82.1)
	1983	436±235	0.14	(0.030-1.32)	14	20.7	(9.75-157)
	1982	406±121	0.11	(0.03-0.20)	11	23.4	(11.5-47.0)
	1981	426±163	0.19	(0.05-0.43)	10	54.6	(7.67-127)
Outside Controlled Fishery Zone							
Petit Rocher	1984	310±103	0.033	(0.014-0.052)	15	7.90	(4.10-25.8)
	1983	310±56	0.044	(0.020-0.069)	12	9.02	(2.63-20.52)
	1982	380±95	0.060	(0.040-0.100)	10	14.0	(7.1-32.3)
	1981	------	-----	----------	--	----	----------
Heron Island	1984	387±181	0.016	(0.010-0.028)	15	3.30	(1.60-13.8)
	1983	410±211	0.020	(0.010-0.028)	13	4.50	(1.88-9.41)
	1982	395±144	0.03	(0.02-0.03)	9	5.32	(3.51-10.1)
	1981	419±139	0.04	(0.03-0.09)	10	5.80	(4.36-12.0)

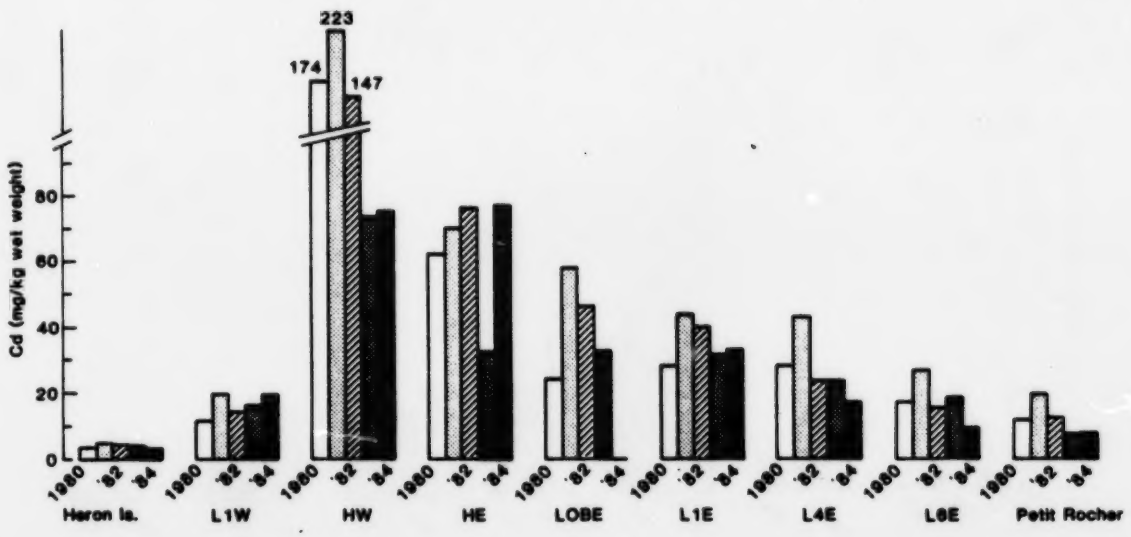

Figure 2 - Geometric mean cadmium levels (mg/kg wet wt.) in lobster digestive glands between 1980 and 1984 in the area of Belledune Harbour, New Brunswick.

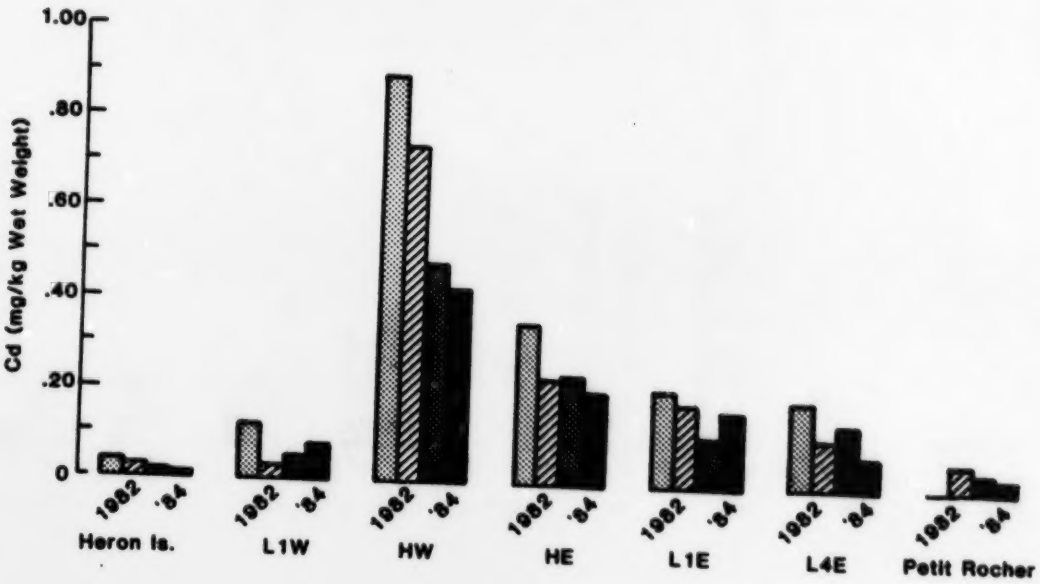

Figure 3 - Geometric mean cadmium levels (mg/kg wet wt.) in cooked lobster meat between 1980 and 1984 in the area of Belledune Harbour, New Brunswick.

The major source of Cd to lobsters which have wandered into the area after the opening of the treatment plant is likely sedimentary Cd from previous discharges. Flushing of Cd-enriched sediments from the harbour and remobilization of this Cd making it accessible to the biota of the area may be the major mechanism of continued Cd uptake by lobsters currently residing in the area. It is not possible to determine the ultimate Cd level in the lobster population given the amount of Cd currently entering the marine environment, nor how long the system will take to reach this level. Monitoring must continue for some period, although the frequency of sampling (currently once a year) may possibly be reduced.

LEAD LEVELS IN COOKED LOBSTER MEAT

In 1983, chemists at the smelter determined Pb levels in cooked lobster meat samples. Their results gave mean cooked meat Pb levels of 1.87 mg Pb/kg wet wt. (N=12) from Harbour West lobsters, 3.09 mg Pb/kg wet wt. (N=5) from Harbour East animals and 1.31 mg Pb/kg wet wt. (N=3) from the L1E site (Uthe et al. 1984). Control lobsters (Heron Island) had a cooked meat mean level of 0.35 mg Pb/kg wet wt. Intercomparative studies between this laboratory and our own were carried out in 1984. The results showed that the smelter laboratory reported higher Pb levels than the accepted values in blind reference materials. Split samples of cooked meat from Harbour West lobsters collected in 1984 showed that a consistent difference in the measured amounts of Pb existed between the two laboratories, this difference being described by the following regression equation:

$$[Pb]_{Halifax} = 0.060 + 0.564\ [Pb]_{Smelter}$$

(coefficient of determination of = 0.973; N=17)

Assuming that this relationship was also true in 1983, it is possibly by using this equation to estimate an average Pb content in Harbour West cooked meat for 1983. The corrected mean is 1.25 mg Pb/kg wet wt. This equation does not apply to the determinations carried out on cooked meat from Heron Island lobster where the reported levels of Pb were much lower than those for Harbour West. As a result of these studies it was decided that Pb measurements in cooked meat samples in 1984 would be carried out in the Halifax Fisheries Research Laboratory.

Geometric mean Pb levels in cooked meat from lobsters captured within the harbour were approximately 1.0 mg/kg wet wt. compared to a mean level of 0.051 mg/kg in cooked meat from lobsters from the control site, Heron Island (Table 3). The harbour value is similar to the range in Pb values of 0.01-2.3 mg/kg wet wt. (mean value = 0.65; N-115) reported in a study of commercial lobster meat carried out by the Inspection Service of the Department of Fisheries and Oceans in the early 1970's (A. Gervais, personal communication). This same group reported a Pb range of 0.05-1.56 mg Pb/kg in commercial meat prepared from lobsters captured in the controlled fishery zone around Belledune Harbour in 1981. In contrast with the 1983 study where a significant relationship between Pb and Cd levels in cooked meat was reported (Uthe et al. 1984), no such relationship was found in 1984. The highest Pb level found in 1984 was 2.69 mg/kg whereas in 1983 values greater than 12 mg Pb/kg had been reported.

Table 3. Mean (± standard deviation) cadmium and lead levels (mg/kg wet wt.) in cooked lobster meat in 1984.

Sample Site	Cd				Pb		
	$\bar{X}g$	$\bar{X}$±s.d.	Range	N	$\bar{X}g$	$\bar{X}$±s.d.	Range
Heron Island (control)	0.016	0.016±0.015	0.010-0.028	16	0.051	0.052±0.014	0.042-0.069
Harbour West	0.512	0.811±0.725	0.054-2.69	15	1.012	1.182±0.691	0.377-2.63
Harbour West (held 9 days)	0.356	0.522±0.450	0.076-1.45	15	1.091	1.216±0.605	0.446-2.42
Combined Harbour West	0.427	0.667±0.611	0.054-2.69	30	1.050	1.199±0.690	0.377-2.63
Harbour East	0.203	0.340±0.366	0.040-1.08	15	0.98	1.137±0.658	0.658-3.06

It was known from earlier studies (Uthe 1980) that Cd was not eliminated by contaminated lobsters held live in clean water. In the present study lobsters were held at least overnight prior to slaughter. In certain instances they were held 1-2 days prior to killing. The effects of short-term lobster storage and the autopsy procedures on Pb levels in cooked meat were unknown. In order to assess possible changes in Pb levels, a group of Harbour West animals were held for 9 days prior to slaughter (Table 3). There was no significant effect on Pb levels. Study of the autopsy procedures e.g. doubling the homogenization time, doubling the number of cutting operations, etc., showed no effect on cooked meat Pb levels.

COPPER, SILVER AND ARSENIC IN COOKED LOBSTER MEAT

Cu, Ag, and As were determined in cooked lobster meat samples in 1983 (Table 4). Although the mean levels of these metals appeared somewhat elevated in Harbour West samples compared to samples from just outside the harbour (L1W site) and the control site (Heron Island) none of the differences were statistically significant. Cu levels in cooked meat did not appear elevated compared with literature data (Uthe et al. 1984) although these comparisons were not strictly valid since the effect of cooking on Cu levels in lobster tissues had not been determined. Arsenic levels in harbour lobsters did not appear to be elevated compared with levels found in lobsters from other areas (Freeman and Uthe 1974). Ag levels were also in the range of reported levels of Ag in lobster muscle (Chou et al. 1983, Chou and Uthe 1978).

BIOLOGICAL IMPLICATIONS OF CADMIUM CONTAMINATION IN BELLEDUNE HARBOUR

Lobsters captured within Belledune Harbour do not appear to be suffering ill effects from the presence of trace metals in their tissues at the levels listed above. Lobsters in the harbour grow and molt at expected rates for the region (Levaque Charron personal communication). Haya et al. (1980) were unable to find a Cd-induced effect on the adenylate energy charge in a number of lobster tissues. There were no differences in tissue levels of Na^+,K^+,ATPase or levels of residual ATPase between harbour and control lobsters. Odense and Annand (1980) could not detect any histopathological changes in green glands, digestive glands or gills from harbour lobsters compared with contol tissues, however, the authors cautioned that such a restricted examination of only three tissues did not mean that the animals were free from Cd-induced effects.

COMMERCIAL FISHERY CONSIDERATIONS

Commercial lobster meat packs have been prepared from lobsters captured in the controlled fishery zone surrounding Belledune Harbour since 1980. The average level of Cd in cooked meat from lobsters captured within this zone (L1E and L4E sample sites) has decreased since 1981 (Table 5). None of the product prepared from these lobsters over the five years has been declared unfit for sale due to its content of trace metals. Intensive fishing of Belledune Harbour was carried out in the summer of 1980 and approximately 22,000 lobsters were removed and destroyed. This is approximately equal to the annual recruitment in the harbour prior to the fishing ban in 1980 (Levaque Charron, personal communication). This, plus the opening of the treatment plant in November 1980 and the diversion of the treatment plant effluent discharge to the east of the harbour was expected to increase the rate at which contaminated lobsters would

Table 4. Mean levels (mg/kg wet wt.) of copper, silver, and arsenic in cooked lobster meat. (Standard deviations are shown).

Sample Site	N	Cu	Ag	As	Cd
Heron Island (control)	10	19.60±3.16	0.407±0.862	2.30±0.41	0.029±0.025
L1W	10	19.74±6.65	0.432±0.215	1.93±0.68	0.143±0.323
Harbour West	10	22.77±3.62	0.493±0.127	3.92±2.75	0.85±0.50

Table 5. Estimated mean cadmium levels (mg/kg wet wt.) in cooked lobster meat commercial packs prepared from various combinations of lobsters captured in the area of Belledune Harbour.

	Observed Cd levels				Calculated Cd levels in commercial packs		
Year	Harbour West	Harbour East	L1E	L4E	B Hb*	CFZ**	CFZ+ B Hb***
1981	0.89	0.35	0.21	0.19	0.62	0.20	0.41
1982	0.74	0.23	0.18	0.11	0.49	0.15	0.32
1983	0.480	0.240	0.110	0.140	0.36	0.13	0.24
1984	0.427	0.203	0.167	0.072	0.32	0.12	0.20

* - Harbour estimate (Harbour West/2 + Harbour East/2)
** - Controlled Fishery Zone estimate (L1E/2 + L4E/2)
*** - Harbour estimate/2 + Controlled Fishery Zone estimate/2

disappear from the harbour, however, Cd levels in 1981 were higher than in 1980. Evidence presented earlier (Uthe et al 1982) suggested that muscle Cd levels had peaked in 1979 and decreased thereafter, including between 1980 and 1981.

It is of interest to investigate the possibility of reopening the harbour to commercial fishing. Obviously Cd levels in the digestive gland from harbour lobsters are still high enough to prohibit reopening of the harbour as a normal commercial fishery for the live lobster trade. Two possibilities remain: the reopening of the harbour as a separate fishery from the controlled fishery zone and processing of these animals in the manner currently used for lobsters from the controlled fishery zone, or the harbour could simply be reopened along with the current controlled fishery zone as a single controlled fishing zone. The predicted meat Cd level for both approaches is shown in Table 5 for all years between 1981 and 1984. The combination of the harbour and the current controlled fishery zone in 1984 would have yielded a commercial product with an average Cd level of 0.20 mg/kg, a level comparable to that present in the commercial product produced from the controlled fishery zone in 1980 (0.20 mg Cd/kg) and 1981 (0.19 mg Cd/kg) (Uthe et al. 1983).

Reopening of the harbour in this manner would have an additional consumer benefit. Tagging-recapture studies carried out in 1980-1981 on lobsters captured and released within Belledune Harbour showed that 20.8% of the lobsters tagged in 1980 were recaptured outside the harbour during the 1981 commercial fishery. Of the total number of tagged lobsters recaptured outside the harbour 46% were caught outside the controlled fishery zone (Uthe et al. 1982). This reflects the usual wandering rates of lobsters in the area (Levaque Charron and Eljarbo 1981). Lobsters wandering out of the harbour into the open fishery are sold within the normal commercial operation. Fishing the harbour as suggested above would prevent a significant number of harbour lobsters from wandering outside the harbour and controlled fishery zone into the open fishery. Overall the effect would be a reduction in consumer exposure to Cd, especially for those consumers in the vicinity of Belledune Harbour who consume relatively large numbers of lobster compared to the population at large.

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REFERENCES

Berman, S.S. 1984. ICES seventh round intercalibration for trace metals in biological tissue. ICES 7/TM/BT (Part 1). Preliminary report. International Council for the Exploration of the Sea. Statutory Meeting. Paper C.M. 1984/E:44. 46 pages mimeo.

Chou, C.L., J.F. Uthe, J.D. Castell, and J.C. Kean. 1983. Heavy metal interaction in juvenile American lobster (Homarus americanus). Paper presented at the Tenth Annual Aquatic Toxicity Workshop, Halifax, Nova Scotia, Nov. 1983. Can. Tech. Rep. Fish. Aquat. Sci. - in press.

Chou, C.L. and J.F. Uthe. 1978. Heavy metal relationships in lobster (Homarus americanus) and rock crab (Cancer irroratus) digestive glands. International Council for the Exploration of the Sea. Statutory Meeting. Paper C.M. 1978/E:15. 8 pages mimeo.

Freeman, H.C. and J.F. Uthe. 1974. Geographical distribution of cadmium and arsenic in lobster digestive gland. International Council for the Exploration of the Sea, Statutory Meeting. Paper C.M. 1974/E:16. 3 pages mimeo.

Freeman, H.C., J.F. Uthe, and B. Flemming. 1976. A rapid and precise method for the determination of inorganic and organic arsenic with and without wet ashing using a graphite furnace. Atomic Absorption Newsletter. 15: 49-50.

Haya, K., C.E. Johnston, and B.A. Waiwood. 1980. Adenylate energy charge and ATPase activity in American lobster (Homarus americanus) from Belledune Harbour. p. 85-91. In J.F. Uthe and V. Zitko (eds.) Cadmium pollution of Belledune Harbour, New Brunswick, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 963.

Holden, A.V. and G. Topping. 1981. Report on intercalibration analysis in ICES North Sea and North Atlantic baseline studies. ICES Coop. Res. Rep. No. 80.

Levaque Charron, R.L. 1981. Marine environmental impact survey of the Belledune Harbour area, New Brunswick, for the period May 1979 to April 1980. Centre de Recherche Noranda. Internal Report No. 389, Pointe Claire, Quebec, iv + 44 p.

Levaque Charron, R.L. and I. Eljarbo. 1981. Lobster growth study of the Belledune, New Brunswick area, 1973-1978. Centre de Recherche Noranda, Technical Memorandum No. 110: vi + 47 p.

Odense, P.H. and C. Annand. 1980. A preliminary study of the histology of the hepatopancreas, gill, and green gland of American lobsters (Homarus americanus) collected from the Belledune area of the Bay of Chaleur. p. 93-107. In: J.F. Uthe and V. Zitko (eds.) Cadmium pollution of Belledune Harbour, New Brunswick, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 963.

Uthe, J.F. 1980. Studies on the forced depuration of cadmium from American lobster (Homarus americanus). p. 77-80. In: J.F. Uthe and V. Zitko (eds.) Cadmium pollution of Belledune Harbour, New Brunswick, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 963.

Uthe, J.F., C.L. Chou, and D.G. Robinson. 1980. Cadmium in American lobster (Homarus americanus) from the area of Belledune Harbour. p. 65-72. In: J.F. Uthe and V. Zitko (eds.) Cadmium contamination of Belledune Harbour, New Brunswick, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 963.

Uthe, J.F., C.L. Chou, and T. Stewart. 1984. Report on 1983 investigations into cadmium and lead contamination of American lobster (Homarus americanus) from Belledune, New Brunswick. Levels of copper, silver, and arsenic in cooked meat from lobsters captured in the area of Belledune, New Brunswick. - an addendum. Report prepared for the January 24, 1984 meeting among officials of the Department of Fisheries and Oceans, Health and Welfare Canada and Brunswick Mining and Smelting Co. Ltd. Ottawa. 13p + 4 p.

Uthe, J.F., C.L. Chou, D.G. Robinson, and R. Levaque Charron. 1983. Cadmium in American lobster (Homarus americanus) from the area of a lead smelter. p. 194-197. In: W.C. McKay (ed.). Proceedings of the ninth annual aquatic toxicity workshop: November 1-5, 1982, Edmonton, Alberta. Can. Tech. Rep. Fish. Aquat. Sci. 1163.

Uthe, J.F., C.L. Chou, D.G. Robinson, and R.L. Levaque Charron. 1982. Cadmium contamination of Belledune Harbour, New Brunswick, Canada - Studies of American lobster (Homarus americanus) during 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1060: 1060: iii + 10 p.